# SIMULATION OF AN AIDS TO NAVIGATION MAINTENANCE SYSTEM

JOHN G. MARTINEZ

U. S. NAVAL POSTGRADUATE SCHOOL

NAVY MANAGEMENT SCHOOL

Monterey, California

# SIMULATION OF AN AIDS TO NAVIGATION MAINTENANCE SYSTEM

by

John G. Martinez
LT, USCG

Class of 1961

TABLE OF CONTENTS

## LIST OF TABLES

ABSTRACT

The workings of the U. S. Coast Guard aids to navigation maintenance system is described. Emphasis is placed upon the operation of the buoy tender class cutter to maintain buoys and minor aids. Based on the realization that the Coast Guard exists to serve more than one operational function and that these functions at times compete for the resources made available to the Service, the assumption is made that the Coast Guard needs a method to measure present accomplishment of its aids to navigation functions and a way to test proposed changes before they are adopted. This paper accepts the Monte Carlo simulation technique and attempts to construct a conceptual model of the operations of a Coast Guard District to maintain a system of aids to navigation with variable responsibilities for search and rescue, logistics, and ice breaking duties.

## INTRODUCTION

In the legends and folktales of Japan, there is the story of the mariners who have frequently navigated a safe return to port from their fishing grounds by using as landmarks three prominent trees, windblown and tortured into distinctive shapes. To the fishermen, these trees identified the promontory of the peninsula which shielded the harbor's entrance. In stormy weather or fog shrouded seas, the men sought the trees as clear indication of where to change course. At the story's climax, disaster strikes the sailors when they are almost within their haven and safe from the sea. While they have been fishing, someone has cut down one of the trees! The sailors do not identify their landmark, cannot fix their position, and thus perish in shipwreck at the harbor's entrance.

The modern mariner has more to guide him than just the wind tortured tree on a promontory. A maritime nation's assistance commences with charts and sailing directions depicting its coasts, includes almanacs and mathematical tables and extends to radio aids, lighthouses, lightships, lighted and unlighted buoys (some with sound signals), fog signals, daymarks, and systems of pilotage. The system is integrated to provide coordinated information to the mariners who ply the nation's waters. Yet the mariner approaching

an aid must face the same problems of dependability and identification which plagued the Japanese fishermen in the story.

This paper discusses one type of the many different aids to navigation used in American waters: buoys. The United States Coast Guard now maintains about 20,000 unlighted and 3,000 lighted buoys. Buoys outline channels, indicate shoals, mark obstructions, and warn the mariner. They "watch" exposed stations subject to all the effects of sea, current, and weather. They may be damaged, lost, displaced from station, or defaced by birds. They may exhibit the incorrect light characteristic or even no light, and they may break their moorings to become drifting menances to navigation. Yet, in spite of their shortcomings, buoys can be an inexpensive, reliable means of guiding the mariner and may be the only feasible means to warn him of danger.

The dependability and ultimate usefulness of buoys is a direct function of the care they receive. Such care is the responsibility of buoy tender class cutters, Depots, and Light Attendant Stations. However, maintaining aids to navigation is not the only responsibility assigned to these units. Tender class cutters may perform such additional tasks as search and rescue, law enforcement, ice breaking, and transporting cargo and personnel. Depots are frequently combined with Bases which have general shore functions. Light Attendant Stations, where established, may also operate major

lighthouses and radiobeacons or the light attendant function may be performed as a colateral duty of a Lifeboat Station. These conflicting demands have varying effects on the unit's maintanance of aids to navigation.

It is not always possible to measure the effectiveness of a unit which is performing multiple functions. One glibly states that single objective organizations concentrate all their resources to achieve their goal; but one reluctantly pinpoints the policies, procedures, or equipments of an organization which positively inhibit the accomplishment of multiple goals.

To what extent does the assignment of a buoy tender class cutter to search and rescue duties retard its efforts to maintain aids to navigation? Are these functions so independent as to warrant vessels designed to perform buoy tender duties and additional cutters for search and rescue? Is maintaining aids to navigation such a steady requirement and search and rescue duties so erratic in occurrence that it would be wise to combine these responsibilities? This might mean that all cutters should be replaced by tenders.

What is the seasonal effect of weather on scheduling maintenance of aids? In order to accomplish annual servicings of aids in a brief time, would it be a reasonable policy to concentrate buoy tenders in southern waters in wintertime and in northern waters in summertime? How might the repairs to aids after storms like hurricanes be handled under such a policy?

What is the effect on the schedule of buoy tender operations of the use of different type buoys in the same channel? Might not the use of only lighted buoys (of the same class and some with sound apparatus) simplify the scheduling of maintenance operations?

If all costs were considered, might it not prove more economical to equip the buoy tender with the tools to allow it to overhaul a buoy on station rather than return it to a Depot for such work?

On what projects should limited research money be expended to improve aids to navigation equipment? What developments or changes in present equipment would most reduce the cost in money and time of the maintenance of aids to navigation?

These are a few of the questions which, if posed, would be answered but which could not be answered finally without considerable experimentation. Some of the experiments would extend over several years. These questions, and many more, are vitally important to the Coast Guard. Any measure which will enable the service to perform a function with reduced expenditure of the resources of men, material, and money demands attention. The Coast Guard faces ever increasing demands for its services but must operate with stable or only slightly increasing grants of resources. It must perfect ways to enable it to accomplish more with what is available.

This paper inquires into the policies, procedures, and schedules which control the inspection, servicing, and relief of aids (especially buoys) by the Coast Guard. The attempt is made to construct a conceptual model of all the factors which control the scheduling of a buoy tender class cutter. The methods of manipulating the model to measure present scheduling procedures is described, and the rules for testing proposed policies, procedures, or new equipments are listed.

# CHAPTER I

## AIDS TO NAVIGATION ORGANIZATION

On 30 June 1959 the United States maintained 39,932 aids to navigation. Of these, 348 were manned light stations and 32 were lightships. There were many unmanned lights and about 23,300 buoys--20,000 unlighted buoys and 3,000 lighted buoys. A minor proportion of these buoys mounted sound equipment such as bells, gongs, horns, or whistles. Included amongst these aids were electronic aids to navigation such as radio beacons and loran stations. These aids to navigation were located throughout almost all the United States, its overseas possessions and Territories, and military installations. These aids were used extensively by the mariner plying our waters and to a lesser extent by the aviators who found the electronic emissions helpful.

### Aids To Navigation Becomes A Coast Guard Function

The United States Coast Guard is the service which maintains the American system of aids to navigation. The Coast Guard, which had been occupied with duties of law enforcement and life saving, received this additional duty in 1939 when, by Reorganization Plan No. II of 9 May 1939, issued under authority of the reorganization powers granted to the President by the Reorganization Act of 1939

(3 April 1939), the Lighthouse Service "joined" the Coast Guard. The Bureau of Lighthouses, founded as a service in the Department of Commerce in 1910, had developed an organization devoted to all aspects of aids to navigation. On the other hand, the Coast Guard had devoted its energies and organization to the fields of life-saving and law enforcement at sea, more especially at that time to the enforcement of "Prohibition." Conditions had changed for both services and it appeared beneficial to combine them. The buoy tender at the harbor's entrance could be used for rescue too, while the patrolling cutter could relight an extinguished buoy. Today's Coast Guard reflects this marriage of duties by its organization which gives importance to these various duties and by the cutters which are designed to perform aids to navigation functions in addition to search and rescue, law enforcement, and ice breaking duties.

## Scheduling Cutter Duties

The Coast Guard has attempted to solve the problem of scheduling the performance of its various duties in different ways. In some Coast Guard Districts, buoy tender type cutters perform only aids to navigation duties, while in other Districts these same type cutters perform varying duties. There are even occasions when such a cutter will perform only duties unrelated to aids to navigation!

There have always been and probably will always be conflicting demands made upon a cutter. The Coast Guard has been proud that the cutters have performed well in spite of adversity and limited resources. Yet there is a limit to what a cutter can do. The limits to achievement are inherent not only in the cutter itself, but also in the organization and policies that govern and control the performance of duties. It is the scope of these limitations that are sought in this inquiry.

This inquiry is undertaken from the viewpoint of buoys, not because buoys are the most important aids serviced by the tender, but because the maintenance of buoys is the "bread and butter" "always there" function about which the tender's schedule revolves. The men aboard the tender know that no matter how adventuresome, diverting, interesting, or essential other duties may be, there will always be the buoys waiting to be serviced.

Before considering further the work of the buoy tender, it might be well to consider the organization of the Coast Guard and the facilities devoted to aids to navigation functions.

## Coast Guard Headquarters

The Commandant at Headquarters in Washington, D.C., controls the Coast Guard. In the field of aids to navigation, Headquarters devotes itself to policy making, planning, and liaison with other agencies, together with engineering the design of large scale

projects or equipment which will be used service-wide, with procurement of equipment and supplies to fill service-wide requirements, and with editing the publications identifying the aids in the aids to navigation system. The Division of aids to navigation in the Office of Operations has the major coordinating function and works closely with the personnel from other offices. There is much mutual exchange of information and opinion at this level, because the problems encountered cross all Divisions. However, Headquarters does not usually exercise immediate operational control over subordinate commands. Rather, it delegates such control to the Area and District Commanders.

### The Coast Guard District

The Coast Guard has grouped command of its units into twelve geographic regions called Districts, usually under the command of a Rear Admiral. These Districts exercise full operational as well as administrative command over assigned units. It is to the District Commander that the Commandant and Headquarters look for performance of Coast Guard duties.

### The Area Commander

In order to control Ocean Station Vessels far at sea and to give full measure of assistance to rescue operations of broad scope or involving more than one District, the Commandant has created two

Area Commanders: Eastern Area, located in New York and Western Area, located in San Francisco. At present the District Commanders in these two cities serve also as Area Commanders. It is important to know that the Area Commander can assume control of any search and rescue operation and can summon units from other Districts to assist as he sees fit. The Area Commander is aware of the normal assignments of buoy tenders and would usually select a search and rescue cutter that was available to assist. However, he may at times find it necessary or expedient to order a buoy tender to the scene of the rescue.

District Aids to Navigation Officer

In the District Office there is a section of the Operations Division devoted to aids to navigation. This Section controls and schedules all aids to navigation work, publishes Local Notices to Mariners, coordinates aids to navigation work with other Divisions, maintains records, and considers and forwards recommendations for changes to aids to navigation. The control of all units performing aids to navigation duties is vested in this Section.

Shore Units

Mention has been made of the vessels which service aids to navigation. However, shore units also participate in this work. Depots are Coast Guard industrial shore units organized to receive,

overhaul, store, and prepare aids to navigation equipment for use. Bases, which have a more general function, usually include depot facilities. Such units may also have personnel and equipment (boats and trucks) to service local shore and minor aids. The Coast Guard also uses Light Attendant Stations. Such a station is a small unit consisting of only two or three men, a storage area for aids to navigation repair parts, a truck, and, if appropriate, a boat. This unit is assigned the duties of inspecting aids, reporting malfunctions, and frequently maintaining the aid in operating condition by means of emergency equipment until a tender can arrive with a replacement aid or with major equipment to repair the aid.

## The Buoy Tender

The buoy tender is the most versatile of the units assigned aids to navigation duties. The buoy tender is capable of performing almost every function concerning maintenance of aids to navigation that is performed by other units. It usually transports buoys and equipment to and from buoy locations, but it also supplies lighthouses, lightships, loran stations, or other remote units and may perform search and rescue or law enforcement duties. Its high capacity boom, workshops, cargo space, and work boats make it adaptable to many functions. Tenders may be grouped by size into Coastal Tenders about 200 feet long, Inland Waterway and River

Tenders usually of light draft and up to 120 feet long, and Buoy Boats from 38 feet to 65 feet in length.

## Organization Objectives

Briefly we have described an organization devoted to aids to navigation. Such an organization must have objectives and must use criteria to measure accomplishment. The goal is to provide a dependable system of aids to navigation to guide the mariner safely along our coasts, our rivers, and our lakes, and into and out of our ports. The usual measure of attainment is the number of times an aid fails to operate or, through some circumstance, communicates incorrect information. A moment's reflection will convince the reader that the number of failures is a proper measure of attainment of the goal only if one assumes that the layout of the aids is optimal. Actually, a second measure of effectiveness must also be used: the number of complaints about the present system of aids and the petitions for changes. In as much as Headquarters and the Districts prescribe the characteristics and location of aids, this second measure reflects on their attainment, whereas the number of failures tell the effectiveness of the units and personnel which care for the aids.

## Summary

The United States Coast Guard, an organization established to promote safety of life at sea and to enforce United States laws

on the seas,[1] was assigned the additional function of maintaining the American system of aids to navigation in 1939 when the Coast Guard and the Bureau of Lighthouses were amalgamated. The Coast Guard organization has been modified to include these three operational functions.

Operations are decentralized to District Commanders in charge of large geographic areas who plan, schedule, and control the operations of assigned units. On occasion, as when a major disaster strikes at sea, the operational command of district units may be assumed by an Area Commander, who will coordinate the units of several districts to complete the rescue operations.

Buoy tender class cutters are capable of performing many traditional Coast Guard duties in addition to servicing aids to navigation. Not all cutters perform all duties. Some are restricted by design from performing certain functions, whereas operational commitments or decided policy restricts the usual assignments of cutters to distinct types of duties.

The goal of units assigned aids to navigation functions is to minimize "outages" of aids defined as "the failure of an aid to navigation to function exactly as described in the Light List".[2]

---

1. Description and extent of the powers granted the Coast Guard to enforce laws and the geographic limitations imposed may be found in the United States Code, expecially "Title 14, Coast Guard".

2. Chapter 28, Glossary, Aids to Navigation Manual, CG-222.

The difficulties encountered and the limitations inherent in assigning aids to navigations, search and rescue, and law enforcement duties to cutters is the subject of this paper.

# CHAPTER II

## THE CYCLE OF BUOY SERVICING

### Servicing Buoys

Servicing of buoys is usually classed as follows: (1) relief of buoys, (2) periodic replenishment of their acetylene gas accumulators or electric batteries, and (3) emergency servicing operations. Actually, these three types of servicings may all be conducted by a tender during the same cruise. The general scope of the servicing performed by a tender is quoted in the Manual as:

"Among other detail matters, buoy work includes:

> (a) The replacement of acetylene cylinders or electric batteries in buoys on station.
>
> (b) The cleaning, adjustment and often exchange of buoy lighting equipment including lanterns, lamp changers, flashers, valves, burners, and regulators and making of minor repairs to buoys while on station.
>
> (c) The removal of buoys from station, their preliminary cleaning, and their replacement with relief buoys with the changing seasons.
>
> (d) The replacement of damaged buoys and the establishment of new buoys."[1]

### The Cycle of Buoy Servicing

The servicing of buoys to provide a properly watched station can be described by a simple cycle. Disruptions to this cycle cause the difficulties of scheduling.

---

1. Aids to Navigation Manual, Art. 27-1-5G(1).

A. Prior to the relief date, the Depot, where most of the functions of overhaul, repair, and storage are performed, draws a buoy with its necessary equipment and mooring appendages from storage, checks all equipment for proper operation, paints the buoy with the colors of the assigned station, and issues the buoy, equipment, and appendages to the buoy tender.

B. The buoy tender (a vessel especially designed to handle and service aids to navigation) sets the buoy on station. Such work consists not only of transporting the buoy to station, but also of mounting the equipment such as the lantern on the buoy and attaching the mooring appendages. The buoy is then set on the precisely determined station and checked for proper operation or "watching". The tender retrives the previous on-station buoy, cleans off the accumulated marine growth, disassembles the equipment and appendages, and returns this buoy to the Depot for overhaul.

C. The Depot sandblasts, repairs, and paints this buoy, inspects and overhauls all equipment and appendages, then stores it for future use.

D. During the service life of the buoy on station, the tender makes periodic inspections of the buoy to check its position, to inspect its mooring, and, for lighted buoys, to replenish with fuel.

E. This cycle repeats every two years when the Depot, noting the scheduled relief date approaching, commences again to prepare a buoy for the station.

To be precise, we cannot consider the cycle of our example completed until the buoy first placed on station is returned to the Depot, cleaned, inspected, overhauled, and once more in stock. There is an overlap of cycles caused by the requirement that the station never be left unwatched.

<u>Causes of Cycle Disruption</u>

The simple cycle described above may be disrupted by several factors. Weather, together with resultant sea action, is a major influence. Its action may damage, shift off station, or sink a buoy and may also extinguish a lighted buoy or silence a sound buoy. However, passing vessels may accomplish the same feats by striking the buoy. Weakness in any part of a buoy, its equipment, or its mooring appendages which results from manufacturing defects, carelessness in assembly, or cumulative effects of service on station may also cause failure. These outages call for immediate correction. The tender must interrupt its schedule to service or relieve such buoys. Emergency servicings delay the accomplishment of routine scheduled work and may, in an extreme case, delay the routine work until it too assumes emergency status.

Tenders are assigned more duties than caring for buoys. The duties may also interfere with scheduled operations. These other duties include servicing lights and lightships, maintaining minor shore aids, transporting cargo, assisting in search and rescue

work, and ice breaking. During operations, weather may play another disrupting role. It may delay any operation. It may delay by hours or even days the relief of a buoy, or it may delay some other operation, thereby also delaying buoy operations. Also, although not usually a dominant factor, a shortage of buoys, equipments, and appendages (particularly electric batteries) that results from emergency usage that depletes the Depot's stock may impede the best planned schedule.

Summary

The cycle of buoy servicing and the factors which disrupt this cycle are considered by Headquarters when it establishes the policies which govern the aids to navigation system, when it lays out the procedures to be used to accomplish aids to navigation servicings, and when it initiates and later approves new equipment designs for the aids themselves, for the tenders, and for the Depots. Changes in policies, procedures, and equipments are made to increase the efficiency of the aids to navigation system and its maintenance. However, proposed changes may also affect other functions and duties of Coast Guard units. The consequences must be considered when deciding to modify any factor. This paper is devoted to the proposition that methods must be devised to measure the operation of the present organization and to test the influence of any proposed change to the organization. With such information available, decisions can be made which will appear, in retrospect, to be wise.

CHAPTER III

THE BUOYS

In as much as this paper attempts to analyze the factors which influence the scheduling of operations to service buoys, it is appropriate first to describe and explain the buoys and buoyage system used in the United States.

Buoys Defined

"A. A buoy is a moored floating object which may be a metal cylindrical or conical float, or a wooden log (spar). In the case of lighted buoys, the cylindrical float is surmounted by a skeleton framework supporting the lantern. The distinctive shape and color of a buoy serves as a daymark, and in the case of a lighted buoy, the light indicates its presence and meaning at night.

B. Buoys have an advantage over fixed lights and daybeacons, in that they may be readily moored close to the navigational track of vessels so as to mark the side limits of channels and may be easily relocated to meet varying conditions. Buoys are placed in positions where an aid to navigation is needed but where a fixed structure would be impractical to construct."[1]

Lateral Buoyage System of the United States

The system of buoyage used in the United States is known as the lateral system and is based on recommendations of the International Marine Conference of 1889. Under this system, the coloring, shape, numbering, and lighting of the buoys indicate the direction

1. Article 24-1-1, Aids to Navigation Manual, CG-222.

to a danger relative to the course which should be followed. Channel direction for determining buoyage is based upon the course followed by a vessel proceeding "from seaward." Unlighted port hand buoys are cylindrical shaped like "cans" and are black, while starboard hand unlighted buoys are red colored conical shapes called "nuns." The shape of lighted buoys, sound buoys, and lighted-sound buoys have no special meaning under the lateral system--only their number, color, and light have meaning. In order to cover special cases such as channel junctions, horizontal striped buoys are used like the black and red horizontal striped "can" or the red and black horizontal striped "nun." Here, it may be noted, the shape conforms to the topmost color, and the buoy indicates the usually followed channel. Vertical black and white buoys are used as mid-channel or fairway markers. Certain other buoys having no lateral significance are also used: white buoys indicating anchorages, yellow buoys indicating quarantine anchorages, and horizontal striped orange and white buoys indicating some special purpose. Other special buoys, not usually maintained by the Coast Guard, are also authorized. Lighted buoys, sound buoys, or even combination buoys may be used in lieu of the unlighted shaped buoys. Where used, these buoys conform in color and numbering to what would be used on the unlighted buoy--but not to shape.

The lights shown by buoys comply with the lateral system. Lights are distinguished by color and characteristic. The colors

used are green, white, and red. The characteristics of the lights are the frequency and the duration of the light flashes displayed. The characteristics used are as follows: flashing, occulting, quick flashing, interrupted quick flashing, short-long flashing.

Black, port hand buoys show a green or a white flashing or occulting light while red, starboard hand buoys show a red or a white flashing or occulting light. Junction buoys show an interrupted quick flashing light white or green in color if the buoy is left on the port hand and white or red in color if the buoy is left on the starboard hand. Quick flashing lights are used on buoys to indicate a turn in the channel or some danger, such as a wreck, and always indicate caution. The short-long flashing light, white in color, is reserved for use on the mid-channel or fairway buoy.

## Classification of Buoys

Strictly speaking, the classification under the lateral system of buoyage is a classification of "stations" and not of buoys. Such classifications can be readily changed. The change may necessitate only a minor modification to the buoy on station such as renumbering, or it may extend to require a different type or size buoy. Buoys themselves are classified as follows:

> "A. Lighted, lighted sound, and unlighted sound buoys are classified according to:
>
> 1. Diameter.
> 2. Over-all length.

UNITED STATES COAST GUARD

# BUOYAGE OF THE UNITED STATES

Significance of Shapes, Coloring, Numbering, and Light Characteristics

Symbols shown adjacent to Buoys are those used on Charts to indicate such Aids

## LATERAL SYSTEM

### PORT SIDE
ENTERING FROM SEAWARD

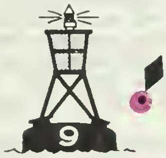
Marks port side of channels and obstructions. To be left to port when passed.
Color: BLACK
Numbering: ODD. (Does not apply to Mississippi River System)
Shape: CAN. (Lighted buoys, sound buoys, and spar buoys, have no shape significance)
Color of Light: WHITE OR GREEN
Light Phase Characteristics: (Does not apply to Mississippi River System)

FLASHING

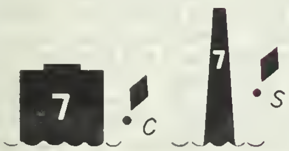
OCCULTING

QUICK FLASHING

Marking important turns, wrecks, etc., where particular caution is required.

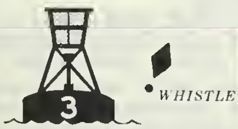



Lighted




Can Spar


Unlighted Bell

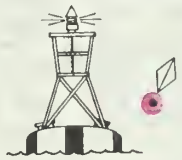



Unlighted Whistle

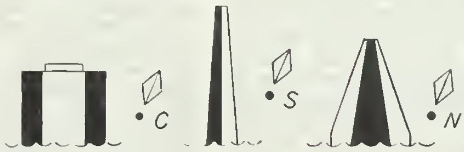
### MID-CHANNEL
ENTERING FROM SEAWARD

Marks Mid-channel
Color: BLACK AND WHITE VERTICAL STRIPES
Numbering: NONE. May be lettered
Shape: NO SHAPE SIGNIFICANCE
Color of Lights: WHITE ONLY
Light Phase Characteristics:

SHORT-LONG FLASHING



Lighted

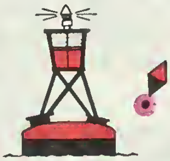



Can Spar Nun

### JUNCTION
ENTERING FROM SEAWARD

Marks junctions and obstructions which may be passed on either side. Preferred channel is indicated by color of top band.
Color: RED AND BLACK HORIZONTAL BANDS
Numbering: NONE. May be lettered
Shape: CAN OR NUN ACCORDING TO COLOR OF TOP BAND. (Lighted buoys, sound buoys, and spar buoys have no shape significance)
Color of Lights: WHITE, RED, OR GREEN
Light Phase Characteristics:

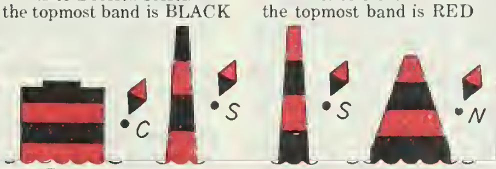
INTERRUPTED QUICK FLASHING



Lighted

Where preferred channel is to STARBOARD the topmost band is BLACK

Where preferred channel is to PORT the topmost band is RED




Can Spar Spar Nun

### STARBOARD SIDE
ENTERING FROM SEAWARD

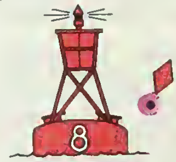
Marks starboard side of channels and obstructions. To be left to starboard when passed.
Color: RED
Numbering: EVEN. (Does not apply to Mississippi River System)
Shape: NUN. (Lighted buoys, sound buoys, and spar buoys have no shape significance)
Color of Light: WHITE OR RED
Light Phase Characteristics: (Does not apply to Mississippi River System)

FLASHING

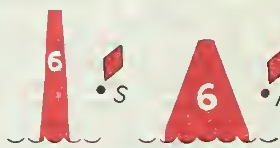
OCCULTING

QUICK FLASHING

Marking important turns, wrecks, etc., where particular caution is required.




Lighted




Spar Nun


Unlighted Bell


Unlighted Whistle

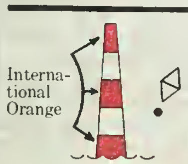
## BUOYS HAVING NO LATERAL SIGNIFICANCE

Color. AS SHOWN: Numbering: NONE. May be lettered. Light Phase Characteristics: Color of Lights: ANY EXCEPT RED OR GREEN

FIXED

FLASHING

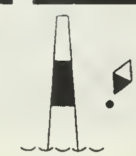
OCCULTING




Special Purpose

Quarantine Anchorage

Anchorage



Fish Net

Dredging

3. Sound equipment:
   a) W - Whistle.
   b) B - Bell.
   c) G - Gong.
   d) H - Horn.
4. Light source:
   a) E - Electric (FE - Flat Electric).[1]
   b) A - Acetylene.
5. RB - Radiobeacon.
6. For example: An 8 x 26 - WE means a lighted buoy, 8 feet in diameter, 26 feet over-all length, a whistle for sound equipment, and powered by electricity.

"B. Unlighted buoys without sound equipment are classified as follows:
1. Standard nuns and cans (Std).
2. Tall nuns and cans (T).
3. Special nuns and cans (SP).
4. River nuns and cans (RIVER).
5. Spars, wood and metal (SPARS)."[2]

Standardization

The U. S. Coast Guard has standardized the type of buoys in use as follows:[3]

A. Lighted Sound Buoys
   10 x 39 - WE
   10 x 39 - WE-RB

1. Flat means that the bottom of the buoy body is flat. In other words there is no counterweight "tube" attached to the body. Being flat, the buoy may be stored standing upright. Lacking the "tube" counterweight, such a buoy is not as stable as other lighted buoys and therefore is used only on sheltered stations.

2. Article 24-2-1, Aids to Navigation Manual, CG-222.

3. Article 24-2-5, Aids to Navigation Manual, CG-222.

A. (Continued)
- 9 x 32 - WE
- 9 x 32 - BE
- 9 x 32 - GE
- 8 x 26 - BE
- 8 x 26 - WE
- 8 x 26 - GE
- 6 x 20 - BE

B. Lighted Buoys
- 9 x 32 - E
- 8 x 26 - E-RB
- 8 x 26 - E
- 7 - FE
- 6 x 20 - E
- 5 - FE
- 3½ - FE

C. Unlighted Sound Buoys
- 9 - B or G
- 8 - B or G
- 7 - W

D. Unlighted Buoys
- Std: 1st, 2nd, and 3rd class
- T: 1st, 2nd, and 3rd class
- SP: 1st, 2nd, and 3rd class
- RIVERS: 19, 18, 15 (inch)
- SPARS: 1st, 2nd, 3rd, and 4th class

Standardization of types of buoys is a long time goal. A considerable number of non-standard lighted, and a few unlighted buoys are still authorized for use. A list of the more prevalent types is given below:[1]

| | |
|---|---|
| 9 x 39 - WE or WA | Converted "C" - E or A |
| 9 x 38 WE | 6 x 22 - E |
| 9 x 32 - BA, GA, or A | 6 x 20 - BA or A |
| 8 x 26 - WA, BA, GA, or A | 6 x 18 - A |
| 8 x 23 - WE, WA, BE, BA, or A | Converted B111 - E or A |
| 8 x 20 - BE, BA, GA, E, or A | 5 x 15 - E or A |
| 8 - W | 4 x 14 - E |
| 7 x 18 - BE, BA, E, or A | 3½ x 10 - E or A |

Buoy Appendages and Equipment

The buoy body itself is only one part of the problem of buoy maintenance; the appendages used to moor the buoy, the equipment needed to provide the light source and its required power, and the

1. Article 24-2-10, Aids to Navigation Manual, CG-222.

sound signal, if applicable, are equally important. The possible combinations are many. Presented on the following page are tabulations (Tables I and II) for some buoys in use. It may be noted by examining these lists that the Coast Guard desires to "standardize" on thirty-seven different buoys: 9 lighted-sound buoys, 7 lighted buoys, 5 sound buoys, and 16 unlighted buoys. Furthermore, these buoys will all be powered by electricity. This is in contrast to the thirty-seven types of buoys listed as "non-standard." In total there are, then, seventy-four different types of buoys used in the service. Eventually, as funds permit new purchases of standard buoys, as non-standard buoys are converted to standard or are retired from service, the buoyage system will consist of only standard types.

Summary

This chapter has presented a description of the buoys and buoyage system used in the United States. It has extended the description of buoys to show that there is considerably more to a buoy than just a steel or wooden float surmounted by a lantern.

TABLE I

LIGHT, POWER, AND APPENDAGE DATA
STANDARD BUOYS

| BUOY TYPE | 10 x 39 | 9 x 32 | 8 x 26 | 7 FE | 6 x 20 |
|---|---|---|---|---|---|
| Power Source | | | Electric | | |
| Lantern Size (mm) | | | 200 | | |
| Preferred Voltage | | | 12 | | |
| No. Battery Racks | 3 or 4 | 2 | 2 | 2 | 2 |
| Type Battery Racks | 44 or 34 | 34 | 34 | 23 | 23 |
| Shackle at Buoy | 2 1/2 | 2 1/2 | 2 | 1 3/4 | 1 3/4 |
| Bridle (in. x ft.) | 1 1/2 x 26 | 1 1/2 x 18 | 1 1/4 x 15 | 1 1/4 x 15 | 1 x 12 |
| Other Shackles (in.) | 2 | 2 | 1 3/4 | 1 3/4 | 1 3/4 |
| Swivel (in.) | 2 | 2 | 1 3/4 | 1 3/4 | 1 1/2 |
| Chain (in) | 1 5/8 | 1 5/8 | 1 1/4 | 1 1/8 or 1 1/4 | 1 1/8 |
| Sinker (lbs.) | 8,500 | 6,500 | 5,000 | 5,000 | 4,000 |
| Buoy Body (lbs.) | 23,360 | 23,000 | 12,500 | 5,760 | 5,400 |
| Equipment (lbs.) | 6,870 | 3,130 | 2,710 | 3,550 | 800 |
| TOTAL (lbs.) | 30,230 | 26,130 | 15,210 | 9,310 | 6,200 |

TABLE II

LIGHT, POWER, AND APPENDAGE DATA
NON-STANDARD BUOYS

| BUOY TYPE | 9 x 38 | 8 x 26 | Conv. "C" | Conv. BIII | 6 x 20 |
|---|---|---|---|---|---|
| Power Source | E or A | A | A | E or A | A |
| Lantern Size (mm.) | 200/375 | 200 | 200 | 200 | 200 |
| Preferred Voltage | 12 | --- | --- | 12 | --- |
| Accumulator Size | A 300 | A 300 | A 300/A 50 | A 50 | A 50 |
| No. Accumulators/Racks | 2 | 2 | 1 or 3 | 2 | 2 |
| Type Battery Racks | 34 | --- | --- | 31 | --- |
| Shackle at Buoy | 2 1/2 | 2 | 2 | 1 3/4 | 1 3/4 |
| Bridle (in. x ft.) | 1 1/2 x 26 | 1 1/4 x 15 | 1 1/4 x 15 | 1 1/4 x 15 | 1 x 12 |
| Other Shackles (in.) | 2 | 1 3/4 | 1 3/4 | 1 3/4 | 1 1/2 |
| Swivel (in.) | 2 | 1 3/4 | 1 3/4 | 1 3/4 | 1 1/2 |
| Chain (in.) | 1 5/8 | 1 1/4 | 1 1/4 | 1 1/8 | 1 1/8 |
| Sinker (lbs.) | 6,500 | 5,000 | 5,000 | 4,000 | 4,000 |
| Buoy Body (lbs.) | 20,610 | 12,500 | 7,700 | 6,900 | 5,400 |
| Equipment (lbs.) | --- | --- | --- | --- | --- |

Notes (Tables I and II)

Battery racks are described by number of tiers and number of batteries per tier. Therefore, the type 34 rack has 3 tiers of 4 batteries each.

The sinker described is the cement type sinker. Weights given are only approximate in as much as the conditions at each station will determine the type, weight, and number of sinkers used.

The 200 mm electric and the 200 mm acetylene lanterns are not interchangeable. Some acetylene lanterns have been converted to electric lighting apparatus; however, there is a special 200 mm electric type available.

The "preferred voltage" is 12 volts. However, in order to obtain service life or length of time on station, 6 volts is sometimes used. The flashers employed for each voltage may not be interchanged.[1]

1. Articles 24-3-40 and 24-3-50, Aids to Navigation Manual, CG 222.

## CHAPTER IV

## DISTRICT CONTROL OF OPERATIONS

The District Commander is responsible for the proper operation, inspection, and maintenance of all aids to navigation in his District. This responsibility is discharged under the general supervision of the Operations Officer and the specific control of his subordinate, the District Aids to Navigation Officer, who heads the Aids to Navigation Section of the Operations Division.

### The Operations Plan

The basic outline of organization for District units and the controls for their operations is presented in the District Operations Plan. This plan assigns missions to and specifies the command relationships among the units. Appendixes to the plan cover anticipated situations as "Hurricane Plan","Disaster Plan", "Ice Breaking", "Aids to Navigation." It is this document which plans whether buoy tenders are to confine their efforts to aids to navigation work except for emergency conditions or to join in performing search and rescue duties on a regular basis.

The aids to navigation portion of the plan lists each unit's responsibilities for aids to navigation. Not all Districts follow the same policy when assigning such responsibility. Two extreme methods may be cited. In New York harbor, the aids are the mutual

responsibility of all the tenders based in New York. In the 8th Coast Guard District, extending from Florida through Texas, each tender is assigned primary responsibility for designated aids. In New York harbor, one tender is always on stand-by to correct a reported discrepancy. This is feasible, because the tenders operate in the same area and from the same base. However, in the 8th District, the coastal tenders operate from two major depots and care for aids in different geographic areas. Each tender corrects the reported discrepancies in its own area.

## Scheduling

The scheduling of aids to navigation work is the responsibility of the District Aids to Navigation Officer. Under the conditions described above for New York harbor, he schedules the work which each tender shall perform each week. However, when responsibility for aids has been delegated to the tenders, these vessels usually schedule their own work and submit the schedule to the District for approval or veto. Advanced planning is required to allow the depot to prepare the required buoys and equipment, so the schedules are set about two weeks in advance.

## Servicing Policies

Policy criteria covering the servicing of aids to navigation have been established by the Commandant and published in the Aids

to Navigation Manual. These must be considered when planning the tender's schedule. The criteria respecting buoys are as follows:

> "Relief of buoys.--Due to recent adoption of the vinyl painting system, the painting of buoys is no longer considered one of the controlling factors in determining the frequency of relief of buoys.
>
> (1) Hereafter, all vinyl-painted metal buoys shall be relieved at intervals not to exceed three (3) years. Relief intervals may be more frequent depending on the need therefor as determined by the District Commander.
>
> (2) All buoys shall be inspected annually for the purpose of accurately checking position, appearance, and proper operation.
>
> (3) Lighted buoys and unlighted sound buoys shall be serviced at intervals not to exceed twelve (12) months. Such servicing shall include but not be limited to recharging, renewal of faulty parts, overhaul or renewal of mooring, cleaning and paint touch-up, all as required."
>
> "Removal of buoys in winter.--Except in cases of harbors, channels, etc., of special importance, buoys liable to be damaged or swept away by floating ice shall be removed on the approach of freezing weather and unlighted buoys correspondingly colored and marked, put in their places where necessary. In the spring, as soon as ice conditions permit, the winter buoys shall be replaced by those to be maintained during the summer."
>
> "Lost buoys, moorings, etc.--In the event of loss of moorings, buoys, or appendages, every practicable effort shall be made by the District Commander to recover them."[1]
>
> "Servicing (operational maintenance) and relief.--All buoys shall be serviced as often as necessary, and in any event at least once each year. Vinyl-painted buoys shall normally be relieved once every 2 years; other buoys, once each year as

1. Article 3-1-5, Aids to Navigation Manual, CG-222.

heretofore. This shall not preclude the relief of a buoy at more frequent intervals due to special circumstances."[1]

"Tender-class cutters are required to check each aid passed for proper characteristic and position."[2] Although not so stated, it is expected that the tender will immediately correct the deficiency.

## Tender Orders

There must be a way to modify the tender's schedule when more pressing aids to navigation work occurs or when the tender must perform work not normally its responsibility. The procedure used to accomplish this is the Tender Order. Tender Orders are issued by the District Commander. Tender Orders provide for servicing of aids to navigation, supplying outlying units with food, water, and fuel, transporting cargo including aids to navigation, establishment or disestablishment of aids including temporary aids, and emergency servicing of an aid by a unit not normally assigned responsibility for the aid. They are granted precedence over all scheduled work. Completion of Tender Orders is usually reported by message, while a list of all outstanding orders is included in the weekly report of operations submitted to the District. The tender tabulates and includes the time required to accomplish the Tender Order, for such time forms the basis for charging others for Coast Guard efforts to repair damaged aids to navigation.

---

1. Article 24-7-5, Aids to Navigation Manual, CG-222.

2. Article 27-1-5, Aids to Navigation Manual, CG-222.

Search and Rescue

Tender class cutters are not usually assigned only search and rescue duties, because these vessels are essential to maintaining aids to navigation. When sufficient numbers of cutters are available to answer effectively the probable number of search and rescue cases, the tenders are usually allowed to perform only aids to navigation functions including stand-by duties to correct deficiencies. However, when there are insufficient cutters or when the available cutters are otherwise occupied, the tenders are required to assume search and rescue duties including cruising to locations within the District close to the probable scene of rescue operations. In accordance with the priorities of the District Operations Plan, the tender may be shifted into such duty by gradually reducing the stand-by interval within which the vessel must be prepared to get underway until the tender is actually proceeding to a search area or to a port to "cover" a distress potential area. Tenders which are already underway must expect to be diverted to the scene of a distress call if they are the closest unit able to provide assistance.

Supply and Logistics Services

Although a tender is capable of carrying personnel and cargo, particularly food, water, and fuel to all types of units, it is usually scheduled to perform such functions only for lightships. Providing such services for other units is directed by the District, either by a Tender Order or a Special Operations Order.

## Summary

Tender operations are controlled by the District Aids to Navigation Officer under the supervision of the District Commander. Schedules are prepared considering the requirements of the aids to be serviced, the weather conditions to be expected, the capabilities of the tender, and the ability of the depots to provide the required buoys and equipment. The tender has some voice in the schedule. This is expressed in its frequent reports and projected schedules. Its recommendations are important especially when it has been delegated responsibility for designated aids and told to plan the work. Other Coast Guard duties may at times be imposed upon the tender because of need and because of the tender's availability and versatility. Yet it must be remembered always that such duties, although essential and humanitarian in nature, are diversions of the tender from the duties for which it is particularly suited and to a large extent irreplaceable--tending buoys and minor aids.

## CHAPTER V

## RESEARCH AS AN AID TO OPERATIONS

### Origin of Coast Guard Goals

The amalgamation with the Coast Guard of the Bureau of Lighthouses in 1939 and of the Bureau of Marine Inspection and navigation in 1942 has created an organization devoted to safety of life at sea and to enforcement of United States laws on the high seas and in American waters. The service inspects the ships which put out to sea, issues licenses and certificates to the personnel who man them, maintains a system of aids to navigation to guide them, and provides a rescue service to assist them when in distress. These functions were combined in order to utilize most effectively the resources of men, money, and material that the country invests for these purposes.

The combination of these functions in one service poses problems. Instead of concentrating all resources to one end, priorities must be established which give due emphasis to the importance of each function and which assure that the proper facilities will be available to meet the various needs. The organization of the Coast Guard must strengthen the service's ability to accomplish each of its obligations; the procedures selected must utilize effectively personnel and facilities, and equipments must be developed to serve multiple ends.

Organizations with multiple goals may reach compromise solutions to problems of policy, procedure, or equipments. The requirements to use existing equipments, together with restriction of new funds, weigh decisions towards extremes that emphasize unduly specific facets of the joint organization.

Solutions to Multiple Goals

In the field of operations, which includes search and rescue, aids to navigation, and law enforcement, more than one solution to these problems has been devised. On occasion, the solution chosen has been service-wide in impact and implementation. (When the Coast Guard designed its first tender class cutter, the requirement was laid down for one vessel to perform the functions of rescue and law enforcement, buoy and lighthouse servicing, and ice breaking.) However, solutions to other operations problems have frequently been restricted to geographic areas, to short range time periods, to modification with the turnover of personnel, and to experimentations. What has long been needed is a method of measuring present operations to determine critical factors and the means to conduct experiments to test operating innovations. If such a method is to be adopted, it should be cheap, it should be able to produce rapid results, and it must not endanger the success of real operations or the personnel and equipments committed to the test.

A method meeting these requirements would provide a means to test proposed solutions to problems of policy, procedure, design of new equipments, and phasing of old and new. Decisions could then be based on factual considerations of the results of proposed changes rather than wishful estimates. What is needed is a small scale model of the Coast Guard which could be manipulated to demonstrate the results of proposed changes and which would, in short order, duplicate long periods of time.

The construction of a scale model of the Coast Guard similar to a model railroad layout is out of the question. Such a model, if constructed, would not provide the data needed for decision making. However, other methods of constructing models are available. These models can provide meaningful results to form the basis for decisions.

## Operations Research

During World War II, the U. S. Navy solicited the assistance of mathematicians and scientists to assist the solution of operational problems. These men successfully pioneered the solutions to such problems as ASW screen formations to protect convoys, aircraft search schedules to detect enemy submarines, scheduling of convoys across the Atlantic to reduce cargo congestion in American ports, and a host of other problems. Several techniques were devised and utilized. However, the methods all called for a multitude of

calculations in order to determine meaningful results. The time and cost of such procedures were justified only in war. The development of the high-speed digital computer has slashed the time necessary to obtain a solution while cost has become more reasonable.

Of the several techniques utilized, the one entitled the "Monte Carlo Method" was most widespread. The name derives from a wartime code name. Monte Carlo has fleeting reference to the fact that in the solution method, the principles of probability are adapted to generate operations which are used as the raw material of the problem. An example based on aids to navigation will explain the Monte Carlo technique and also demonstrate how the technique can solve problems of vital interest to the Coast Guard.

Frequency Distribution

First let us explain a frequency distribution. When a lighted buoy is placed on station or recharged with new batteries, calculations are made to determine how long the batteries will power the light. This information is used as a basis for scheduling the next servicing. However, a study of outage reports will reveal that the batteries sometimes fail before expected. If tabulation of the data for electric buoys were made, the tabulation would reveal the number of times such a failure occurred for every number of days on station. Such a tabulation is a distribution of the days to failure with the

frequency of failures which occurred on each such number of days on station. From such a distribution, one can determine the probability of failure--the number of times an event occurred compared to the number of times it could have occurred.

Outages of a buoy are not limited to premature discharge of its batteries. A buoy may be listed as an outage for many reasons. However, without consideration of any of the causes of the outage but only of the definitions, a frequency distribution of the days on station of electric buoys can be tabulated from records. This distribution permits calculation of probabilities of failure--from any cause. With classifications of data by causes, the probabilities of failure from a specific cause can be determined.

Such data, if available for all aids, would permit one to state the expected number of failures that would occur each day and would enable a District Commander to detect immediately any deviation from normal. In essence, this is the method of statistical quality control used in manufacturing plants.

## Monte Carlo Method

The Monte Carlo method uses probabilities to construct a simulated version of an operation. This version is then solved to return the system to normal and the outcome used as the basis for a second probability simulation. Using a series of such calculations to represent successive time periods, the operation of an aids to navigation maintenance system can be simulated. This

simulation, conditioned by probability to represent reality, presents sequences of events to test the workings of any policy.

As an example, consider the policy that an 8 x 26-WE buoy will remain on station 2 years and be recharged with new batteries at the end of 1 year. Using the probabilities of failures in a simulation, it may be found that the buoy has had to be handled so frequently to correct outages of all kinds that a policy of recharging at intervals shorter than 1 year is logical. This new policy, if adopted, would allow for reduced battery capacity and could question several other procedures accepted as standard.

The use of the Monte Carlo simulation method depends first on constructing a conceptual model of the system to be simulated; second, on determining (or assuming) probabilities which reflect the chances of each possible event's occurring; third, calculating the events which occur during the time interval chosen; fourth, repeating the calculations for successive time intervals; fifth, tabulating the results; and sixth, evaluating the simulation. The whole simulation is usually tried again to obtain additional data, because decisions are usually withheld until confirming results are available.

The remainder of this paper is an attempt to construct a conceptual model of an aids to navigation maintenance system with variable responsibilities for search and rescue, ice breaking, and

other duties and with particular emphasis upon the scheduling of a tender to maintain buoys. To be useful to the Coast Guard, the succeeding steps of determining the necessary probabilities and programming the model for calculation on a computer must be accomplished. The computers presently available can readily and rapidly accomplish all calculation to provide the results for evaluation.

## Purposes of Simulation

The purposes of the simulation may be emphasized:

(1) To measure the present accomplishment of aids to navigation maintenance to determine areas for improvement.

(2) To test proposed changes before adoption in order to obtain all their effects and thereby provide a sound basis for decision.

CHAPTER VI

THE OPERATIONS MODEL

## General Description

The Operations Model is the aids to navigation maintenance system in operation. Using daily predictions of the weather, the number and location of "outages" or aid malfunctions, and the number and types of search and rescue cases together with a schedule of aids to be serviced, the model uses decision rules or policies to select the work that the tender(s) will perform that day. The work of the tender(s), the depot(s), and the Light Attendant Station(s) is calculated for the day, the status of all aids updated, and the results retained for the next "day's" calculations. If programmed on a computer, the machine could print out reports of these "daily" activities or summaries of other chosen time intervals. The repitition of these "daily" cycles to simulate any cumulative time period will result in the model's representing conditions in an aids to navigation maintenance system operated under specified policies.

Outputs of the model would be primarily in the form of "operations reports." However, it would be possible to add an "accounting model" which would use these reports to prepare cost reports for all operating units. In as much as money is a real world measure of efficient operation, this model should be included.

The procedures of the Operations Model may be more clearly understood if it is divided into functional sections. For this purpose one may consider the model to have a Status Generator which predicts the daily status of the weather, the number of "outages", the number of search and rescue cases, and the number of Tender Orders that will exist each day. This section of the model will maintain the daily status of each aid and will review all aids to prepare a schedule of those requiring routine servicing or relief for the next "week", "month", or other chosen interval.

In a second section, the model may be considered to have a Decision Section which applies the decision rules or policies entered into the model to determine what work will be undertaken and in what order.

The Operations Model has, as a final section, the Operations Calculator which calculates the work done by each unit during the day. The results are fed into the Status Generator to update the condition of all aids and into an output printer to inform us.

The Accounting Model is considered a separate model; however, if these models were programmed on a computer, the Accounting Model would appear to be integral with the Operations Model--its work would appear as another printed output. The distinction is made here because the Accounting Model is not essential to the Operations Model no matter how relevant and important its output.

## Status Generator

The function of the Status Generator can be understood when one lists the conditions that occur every day in real life to affect the aids and initiate or modify operations. These are as follows: weather, identification and location of outages,[1] the number and type of search and rescue cases, the number and type of Tender Orders issued, and the list of aids that are scheduled for servicing or relief in the near future. This information will be generated each model day by the Status Generator which will (1) update the service life of each aid, (2) forecast, by means of probability calculations, the specific values of the information listed above, (3) scan ahead to predict routine servicing and/or relief of aids, and (4) print out, on demand, the status of all aids.

The techniques employed to generate this information and the parameters or information required is explained in the following step by step description.

Time and the Day of the Week. The day is chosen as the basic unit to be used in the model. This would correspond to a real day, but in actual time would last only so long as the computer requires to complete its calculations. This day may be called "model-day", "machine-day", "time-day", or "computer-day." The day of the week

1. This term includes any malfunction or damage to an aid which calls for correction.

must be determined primarily because not all units work seven days a week. (The depots usually work five-day weeks with premium overtime.) However, a seven-day week is essential to this model in order to "age" realistically the service life of the aids. This feature will provide more realistic input of factors such as search and rescue cases and aid "outages" which are not restricted to a five-day week.

Weather. Every person who follows the sea realizes the importance of weather to daily events. Weather must be included in this model not only because it can delay the operations of the tender, but because it can damage the aids themselves, thereby demanding more work from the tender. The introduction of realistic weather effects into this model which is being devised for the general Coast Guard situation is not simple. However, the following method is suggested.

As far as the tender is concerned, the weather can be divided into three classes:

> Class 1. Little or no effect on the operations of the tender or the aids;
>
> Class 2. Delays or prevents the operations of the tender and and has some adverse effect on the aids;
>
> Class 3. Prevents the operations of the tender and damages the aids.

Using these three classes, the weather for the area to be simulated by the model can be reviewed to determine the probability of occurrence

of each class. Perhaps an example using the Beaufort Scale of Wind Force will demonstrate this:

| Beaufort Scale | Class | Probabilities Spring | Summer | Fall | Winter |
|---|---|---|---|---|---|
| 1 - 5 | 1 | .50 | .65 | .55 | .35 |
| 6 - 8 | 2 | .45 | .30 | .35 | .55 |
| 9 -12 | 3 | .05 | .05 | .10 | .10 |

Note, first of all, that the illustration does not apply to any specific area--it is fictitious. The Beaufort Scale of Wind Force has been utilized as a basis for dividing the weather into three classes. Some other scale might be chosen depending upon the data available for analysis.[1] Probabilities for each class weather are postulated in the illustration in order to show the seasonal change of weather encountered. These changes are essential to introduce into the model the unique storms such as hurricanes and tornadoes which are usually restricted to certain seasons.

In actual practice, each class of weather usually persists for more than one day. This fact should be included in the model. Two methods might be used: (1) a decision rule which states that Class 2 (or Class 3) weather, when occurring, will persist for a specified number of days, thereby obviating a recalculation of the weather until the time interval has elapsed; or (2) a set of probabilities for weather conditions which change not only with the season of the year as illustrated, but also change with the previous days weather.

1. Such other scales may be essential to account for winter icing conditions

For example:

| Beaufort Scale | Class | SPRING PROBABILITIES Yesterday's Weather Class 1 | Class 2 | Class 3 |
|---|---|---|---|---|
| 1 - 5 | 1 | .50 | .45 | .50 |
| 6 - 8 | 2 | .45 | .50 | .40 |
| 9 -12 | 3 | .05 | .05 | .10 |

Note again that the illustration is purely hypothetical. Actual probabilities for the three classes of weather would have to be determined by a statistical survey of the weather records for the area to be simulated.

In the real world, it is not unusual for an area served by a depot or a tender to experience different types of weather in different sections. It is possible to introduce this phenomenon into the model, but it is considered unnecessarily complicating. The sweep of weather usually encountered in United States waters, whereby weather conditions march across an area successively affecting all points, will "average out" to the condition specified in the model: the same weather for the geographic area simulated.[1]

<u>List of Aids to Navigation</u>. No mention has yet been made of the aids to navigation the Status Generator will consider. The model is primarily concerned with the activities of a buoy tender. Such vessels tend buoys but may also, particularly through use of ship's boats, tend minor shore aids either lighted or unlighted. Although

1. It is doubtful that this assumption could be made for a District like the 14th, which includes the Pacific Ocean Area from Hawaii westward. However, even there, the area could be subdivided into sections served by the same depot and the assumption applied.

a tender may perform other functions, except for service to lightships, these other functions are included in the two classifications: Tender Orders or Search and Rescue Cases. The list of aids will, therefore, include three general classifications: buoys, minor shore aids, and lightships. The model will already have much information concerning these aids built into it, so there is no need for the list of aids to include all information used in calculations. An example of an aid listing will illustrate the required information.

For a buoy:

203.5 BUOY LIGHTED-SOUND BLACK AND WHITE WHITE SHORT-LONG 8X26WE SERVICING 400 100

203.5 - The identification number of the aid keyed into the geography of the area. The presently used Light List numbers may work well here.

BUOY - The aid is a buoy.

LIGHTED-SOUND - This is a lighted-sound buoy.

BLACK AND WHITE - This is a mid-channel or fairway buoy painted with vertical black and white stripes.

WHITE - This indicates the color of the light.

SHORT-LONG - This is the characteristic of the light.

8X26WE - This indicates the buoy is a standard buoy 8 feet in diameter, 26 feet in length, has an installed whistle, and uses electric batteries to power the light.

SERVICING - This means that the next scheduled work by the tender is servicing--as contrasted to relief or replacement of the buoy.

400 - This is the day (from model day zero) on which the servicing is scheduled.

100 - The number of days the buoy has been on station.

When performing calculations, this identification data will trigger the model to search for additional information under the headings. For instance, in order to determine whether or not the buoy has failed, the model would seek lists of probabilities of failure under 8X26WE. If it is predicted that the aid failed, the type of failures possible and their associated probabilities would be listed under 8X26WE. In this way, the model can contain much applicable data for every type aid and station. The List of Aids would indicate which of this pre-entered data would be used in calculations.

Read Identification Data on aid.

Determine whether buoy or minor aid.

If buoy

If minor aid, follow minor aid program.

Determine size.

Search for size data to find probabilities of failure.

Using the probability of failure plus weather probability, calculate through random generation, whether aid has failed.

If no failure

Update aid.

Proceed to next aid.

If aid failed

Search size data for probabilities of each type failure. Using these probabilities, calculate, through random generation, the specific type(s) of failure.

Set counter to indicate failure.

Read into the Decision Section the identification data on buoy and the type(s) of failure.

Proceed to consider next aid.

The listing for a minor shore aid would follow the same pattern shown above for buoys. The data would be different. The lightship can also be readily indicated using this format. It must be realized that the actual input listing to a computer would be more abbreviated than that shown in the illustration. Words are used here for clarity.

Schedule for Routine Servicing. The Status Generator performs another task associated with status keeping. This task is reporting the list of aids in need of routine servicing and/or relief. This task is accomplished by searching the list of aids to determine the identity of those whose "due date" will fall within a specified period. This information is reported to the Decision Section and used there with other information and programmed decision rules to schedule work for the depots, tenders, and light attendant stations.

Search and Rescue Cases (SAR). Search and Rescue is an important function of the Coast Guard which cannot be omitted from this model of the aids to navigation maintenance system. Buoy tenders in the various Districts are assigned Search and Rescue duties in accordance with different policies. One purpose of the model is to test these policies.

The specific definition of Search and Rescue cases used in this model is somewhat different from the one normally accepted in the service. It needs be explained. Search and Rescue is considered to include the conduct of searches and rescues, stand-by to perform such duty when relieved thereby of aids to navigation duties, law enforcement duties, and participation in joint exercises which do not include aids to navigation work. Logistics work and ice breaking are not included, as these are considered (in the model) as

subjects of Tender Orders. The model does not intend to include all search and rescue cases performed in an area, but <u>only those which would call for action by a cutter or a tender</u>. What must be considered is that in real life, many cases occur and are completed in which no tender participates, is alerted to participate, or perhaps could participate.

In a manner similar to that used to determine the location, number, and type of aids to navigation outages, the Status Generator must determine the number, type, and location of SAR cases which will occur each day. This is based on a random generation utilizing successively the probabilities conditioned for weather, type of SAR case, and location in the area. This information, when calculated, is transmitted to the Decision Section where, in light of decision rules (policies), the cutters and tenders are assigned to assist.

It is necessary for the Status Generator to use probabilities to predict the occurence of SAR cases. These probabilities must be determined by a separate study of the Operations Data available in the Coast Guard concerning Search and Rescue cases for the area simulated. These probabilities might be changed to test results of a changed number, type, or concentration of SAR cases, but it would be wise to commence simulations with probabilities representing historical data.

SAR PROGRAM

Determine weather

Select SAR probabilities

Calculate the number of SAR cases which will occur

If one or more

If none

Report to Decision Section and Proceed <u>to next program</u>.

Select probabilities for each type SAR case; through random generation, calculate type SAR case.

Select probabilities of duration of SAR case. Through random generation, determine duration of case.

Select probabilities of location of SAR case. Through random generation, determine location of case.

Report facts of case--case number, case type, location, duration to the Decision Section.

Repeat for next case.

<u>Tender Orders</u>. Tender Orders are issued by the District Commander to direct the accomplishment of specific aids to navigation work. In this model, Tender Orders may include logistic support of Light Stations or remote units and the carrying of materials to construct or repair an aid. Ice breaking is also included under Tender Orders. By means of extending the definition of Tender Orders, any function not usually assigned to a tender could be simulated.

The Status Generator uses the same type procedures described above for aids and for Search and Rescue cases to predict the number, type, and duration of Tender Orders. The procedure would be as follows:

Determine weather

Select Tender Order probabilities

Calculate the number of Tender Orders which will occur

If one or more

If none

Report this fact to the Decision Section and proceed to the next program.

Considering weather, select probabilities for each type Tender Order.

Calculate, by means of random generation, the type Tender Order.

Considering weather and type Tender Order, select probabilities for duration of Tender Order.

Calculate, by means of random generation, the duration of Tender Order activity.

Report Tender Order Number, type, and duration to the Decision Section.

Repeat until data for number of Tender Orders determined is completed.

Proceed to next program.

The probabilities to be used for the calculation of Tender Orders must be provided from a statistical study of data on the subject for the area considered. It may be noted that the seasonal character of the weather which is specified for the model allows

one to vary the probability of Tender Orders with the season as well as with the daily weather. This is important for all orders, but especially so for ice breaking.

Parameters. The model has illustrated the use of parameters or data on weather, aids to navigation, search and rescue cases, and Tender Orders. These parameters must be calculated and fed into the model before any simulation can commence. The model is conceived to contain instructions to search for these parameters; they must be available. These parameters may stay constant for many simulations. Weather parameters are the only ones considered varying during a simulation, although such parameters could repeat in a model-year cycle. The other parameters, once determined for an area, would not be changed unless the effect of the change were sought. This might be the result of an engineering innovation in the aids, the tender, or the depot facilities. This change need not be real, but could be postulated to test the effect, say, of doubling the speed of a tender. The same would be true for search and rescue and tender order parameters.

Aids to Navigation System Input. The Status Generator must know the aids to navigation system which it will consider in the simulation. This must be introduced at the start. This information would consist primarily of the identifying data for each aid--buoy, minor shore aid, or lightship included in the system. One

important fact which must be considered is the status of these aids at "time zero" or the commencement of the simulation. Considerable model-time would be required to obtain a realistic spread of servicing and relief dates if the system were to start from nothing. It would be simpler, unless a study of such conditions were the subject of the simulation, to devise an input program already specifying the conditions of aids on station. Real world conditions could be used as a basis, or a computer program devised to compute required inputs.

Although not specified above in the previous explanation of the Status Generator, Tender Orders can and are used to establish new aids and to discontinue existing aids. Such activity changes the original program input of the aids to navigation system. The model can handle this.

Time Until Detection of an Outage. The explanation of the operation of the Status Generator and its reports on the status of aids to the Decision Section of the Operations Model has ignored one problem which exists in an aids to navigation system of the real world--the problem of detection of an "outage."

The Status Generator predicts, through random generation that an aid has failed. Can one assume that this condition is reported immediately or is it more likely that it will exist for some time--hours or days--before it is finally detected and then reported to the Coast Guard?

The model is built upon a knowledge of probability distributions of occurrences--how many times an event has occurred in the past. By the very nature of the question, it seems impossible that data is available concerning the distribution of time between an aid's failure and this fact's being detected and reported. Such information must be based on knowledge of the time of the aid's failure and the computation, by examining the record, of just how much time was required to detect and report the fact. But by definition, knowledge of the time of an aid's failure is tantamount to detection and reporting. Such data cannot be obtained by experiment, because one cannot "play around" with an aids to navigation system by creating failures for someone to detect.

Examination of the data on failures of aids to navigation will reveal that it is based on the reports of failure. This data is the basis of the probability parameters calculated for use in the model. The assumption is made that the aid was in operation until the report is received. In other words, the procedure used in the model, whereby the aid is reported out as soon as the outage occurs, is consistent with the data available.[1]

## The Decision Section

In concept, the Decision Section is one of the simplest parts of the Operations Model. The Decision Section stores information

1. One case in which the report of an aid's outage can be shown not to coincide with the outage in a measurable amount of time is when a tender discovers an aid after a storm and assumes that it went out during the storm.

obtained from the Status Generator: the scheduled routine servicing of aids, the list of outages, the list of Search and Rescue cases, and the list of Tender Orders, together with the day of the week and the weather conditions. It has available from the Operations Calculator information concerning the occupation of the cutter(s), tender(s), depot(s), and light attendant station(s) whose operations are being simulated. In addition, as a program input, the Decision Section has decision rules or policies which guide its decisions.

Decision Parameters. As a basis for the decisions, the Decision Section must have available parameters which describe the various tasks, specify their priorities and list the capacities of the operating units. Using the available information, the Decision Section must assign tasks in an order of precedence to the operating units and change them as events unfold which, in light of the decision rules, call for changes.

The decision rules are the most important input to the Decision Section. These rules determine the interplay of factors, which in turn determines the results of the simulation. The rules will have to be very detailed in order to provide for every possible condition which might occur. It is probable here, more than anywhere else, that difficulty in initially programming the model will be encountered. It will be found that the computer will produce invalid results unless all decision situations are anticipated.

SEARCH AND RESCUE (SAR)

Determine the day of the week

Determine weather

Check SAR Cases

If one or more | If none

Select highest priority case | Proceed to consider next program

Check for availability of cutter(s); compute time(s) to reach scene.

Refer to decision rule to determine whether tender(s) is available for case; check tender(s) condition and position; determine whether tender(s) could participate and time(s) to reach scene.

Determine which available vessel can reach scene most quickly. Refer to decision rule and assign task to vessel.

Repeat check for SAR Cases.

This illustration of the program to assign Search and Rescue (SAR) Cases does not reveal the nature of the parameters and the decision rules which must be considered to reach the decision to assign the task. These may be described by showing the information required at each stage of the illustration.

<u>Select highest priority case</u>. This implies that some ranking of the priority of SAR cases can be made and included in the description of the case. These assigned priorities should be consistent with the information normally available to a Rescue Coordinating Center. For instance, the Status Generator has predicted the duration

of the SAR case. However, in the real world, this information is not available when decisions are made to assign units to a case. In the model, this information will be made available to the Operations Calculator, but should not be used in the Decision Section to rank the cases. Parameters for some other system of priority designation must be used.

Check for availability of cutter(s); compute time(s) to reach scene. Parameters must be available to allow the Decision Section to determine whether or not the cutter can reach the scene, whether the cutter can provide the type assistance needed (i.e. could the type cutter being considered tow the size vessel requiring a tow?), the speed of the cutter under the weather conditions, the distance the cutter must travel to reach the scene, any restrictions on the speed of the cutter imposed by geography such as half speed when leaving harbors or in channels, etc.

Refer to decision rule to determine whether tender(s) is available for case; check tender (s) condition and position, determine whether tender(s) could participate and time to reach scene. In order to consider a tender when deciding assignments of SAR cases, the Decision Section must have available parameters which will detail the condition of the tender (i.e. deck load of buoys or cargo which would delay participation in some types SAR cases), parameters which will state the tender's speed under the weather

conditions, any restrictions on the speed of the tender imposed by geography, the time for the tender to reach the scene if dispatched immediately from her present location, possible delay times such as time to off load cargo, etc.

Determine which available vessel can reach scene most quickly. Refer to decision rule and assign task to vessel. A Decision Rule for this illustration could be as follows: Cutters shall proceed to the scene of distress at maximum speed regardless of legal requirements for reduced speed as in harbors, channels, etc. The closest available cutter will always be ordered to proceed.

Built-in Simplification. It must be understood at this point that a simplification has been built into the model which does not exist in the real world. The model assumes that at the start of the day all the outages, SAR cases, and Tender Orders which will occur that day are known. In the example above, the Decision Section is considering the day's total number of SAR cases. In the real world, this is not possible; because, there is no Status Generator to inform the District Commander what operations the day holds. This, then, is a simplification; it allows the Decision Section to order a tender to proceed to the scene of a SAR case when in a real world situation, the tender may not have known of the case until several hours later and may have proceeded in an opposite direction to perform aids to navigation work. Although the model might be

programmed to report SAR cases at random intervals, such a procedure appears unnecessarily complicating and is, therefore, omitted.

Outages. After the Decision Section has assigned SAR cases to the various operating units, it is ready to consider the assignment of emergency servicing of aid to navigation.

Determine the weather

Check aids to navigation outages

If one or more

If none

Proceed to consider Tender Orders

Select outage of highest priority

Determine whether Light Attendant Station can repair

If no

If yes

Determine whether tender(s) available to service aid

Assign to LAS and schedule for servicing by Tender when next in area

Proceed to consider outage of next highest priority

If no

If yes

Assign servicing of aid to tender which upon completion of its present task can reach aid most quickly

Refer to decision rules and assign task to tender

Proceed to consider outage of next highest priority

Proceed to consider outage of next highest priority

This network of steps in the decision process appears simple, and it is so . . . after the various parameters and decision rules have been specified. The very matter of priority of an outage must be defined. As a general rule, priorities can be established by the type buoy. Perhaps the priority system could be (1) Lighted-sound buoy, (2) Lighted buoy, (3) Sound buoy, and (4) Unlighted buoy. However, ranking within each of these classes must be made. Matters such as type power for lighting, size of buoy, characteristic of light, color of light, etc. must be resolved for precedence. One solution would be to rank all aids in the area in their importance and state that the priority will follow this list. However, type failures must also be considered. A first class can buoy swept off station into the channel might be an outage of higher priority than the outage of a 6X20E buoy. There might also be the case when two adjacent aids in a channel are reported as outages. This situation can be considered to call for quicker correction than would be required if the outages were widely separated.

The Decision Section has available information identifying the aid, its location, and the type outage. The Decision Section must have available parameters and decision rules which will supply the additional information and enable it to rank the outages in a priority system.

This matter of priority has been discussed in some detail to illustrate the type and extent of parameters and decision rules necessary for the Decision Section to operate. In like manner, all other steps taken by the Decision Section can be expanded to list required information.

Determine whether LAS can repair. Will policy allow the Light Attendant Station to do this? Can the LAS repair this type outage for this class buoy? Does weather have an effect on its ability to do this, etc.

Determine whether tender(s) available to service aid. Does the priority of outage take precedence over the present occupation of the tender? Does policy restrict assignment of outage to tender which normally services aid? If more than one tender is available to service aid, which one will be assigned the task, etc.

In order for the Decision Section to operate, these parameters and decision rules must be determined.

Tender Orders. The Decision Section is now ready to consider the Tender Orders.

Determine weather

Determine day of the week

Check for Tender Orders

If one or more — If none

Proceed to next program

Select Tender Order of highest priority

Determine priority of accomplishment

Determine availability of tender(s)

Determine whether Tender Order takes precedence over present occupation of tender(s).

If no

Determine when tender(s) will be available and which one will be closest to scene to commence Tender Order.

Select Tender to accomplish Tender Order and assign task.

Proceed to consider next <u>Tender order</u>.

If yes

Determine which tender can commence to perform Tender Order most quickly.

Assign Tender Order to tender

Proceed to consider next <u>Tender Order</u>.

As explained before, parameters and decision rules to enable the Decision Section to assign tasks must be available.

<u>Schedule For Routine Servicings</u>. The Decision Section has two other tasks which it must accomplish: scheduling the routine work of the tender(s) and establishing the priority of work of the depot(s). As the reader will remember, the Status Generator searches the list of aids to determine those whose routine servicing (or relief) dates fall within a specified period in the future--say a month. This data is reported to the Decision Section. Here, the Decision Section must consider the type aid, its geographic location, its due date,

the availability of equipment to service or relieve the buoy, the tender orders assigned to the tender(s), the present occupation of the tender, the normal cruises, and any policies or decision rules in order to forecast a schedule for the tender(s).

Depot Work. The depots have three distinct functions to perform in relation to buoy work: (1) overhaul of the buoy and its equipment when returned by the tender, (2) storage of buoys, equipments, appendages, and supplies, and (3) preparation of buoys and their associated equipments and appendages for issue to the tenders. The calculation of the time to perform these functions and the maintenance of the status of the work of the Depot will be accomplished in the Operations Calculator. However, specifying the order of accomplishment must be done by the Decision Section. Here will be combined the forecast schedule, the present work load and status, the parameters for capacity, and the decision rules for guidance which will enable the Decision Section to assign the priority for accomplishment of the work performed by the Depot. These priorities will be transmitted to the Operations Calculator, which will calculate the accomplishment of the work in model-time and report the updated status together with the Depot's inventory. This information will be available to the Decision Section upon inquiry and as a printed report to us as scheduled or when requested.

Decision Rules. With due regard to previous statements made herein, the author must emphasize the extensive and detailed information,

predetermined policies, and decision rules which must be fed into this section of the model to obtain results. The examples given to indicate the operation of the Decision Section do not reveal to the reader not familiar with the details of a computer program the all-inclusive, anticipatory nature of the required data. Yet, with such data, successive repitition of programmed steps of decision cycles will enable the Decision Section to make discriminating, sophisticated decisions equivalent to those which would have been made by a human applying the same policies.

## The Operations Calculator

General. The Operations Calculator section of the Operations Model performs the calculations which simulate the activities of the various operating units and maintains an up-to-date record of each unit's occupation and scheduled tasks. In addition, the Operations Calculator utilizes its programmed parameters to calculate proposed operations which the Decision Section needs to reach a decision. Outputs from the Operations Calculator inform the Status Generator of the accomplishment of Tender Orders, Search and Rescue Cases, and aids to navigation tasks. If the Accounting Model were programmed in the simulation, outputs from the Operations Calculator would form the basis of its "pricing out" of operations into cost reports for each operating unit.

Like the preceeding sections of the model, previously described, the Operations Calculator must have available a large number of parameters which describe the activities and capabilities of each unit. These parameters must describe in detail the possible activities of each unit; most of these parameters use a common unit of measurement: time.

Buoy Operations. Consider the case in which the Operations Calculator simulates a tender's servicing of an 8X26WE buoy. The Decision Section will define servicing--maneuvering to pick up buoy, hanging the buoy in the boom rig for servicing, replenishing battery racks, inspecting lantern, checking all equipment, accomplishing repairs, touch-up painting, inspecting mooring, resetting on station, etc. Now these activities are measured in time: so much to do this, so much to accomplish that, etc. A simple simulation could program the time required as a total time for servicing an 8X26WE. This time might be allowed to vary within limits based upon past experience in order to simulate the different types of servicings possible. A method could be used in which the times for each possible activity of servicing could be separately tabulated and the model select those time parameters required to describe the servicing prescribed for the buoy considered. This last method will, perhaps, require less data, for many of the time parameters will be found common to more than one classification of

buoy. For instance, it should take the same amount of time to replenish the battery racks in any 8X26E buoy, lighted or lighted-sound! The Operations Calculator would merely select the time parameters required and sum them to determine how long the tender was occupied in the task of servicing the aid.

Here, it must be explained that checks will have to be included to prevent the tender from doing work which it is not capable of performing. In the example given, the Operations Calculator must determine whether the tender can handle the type aid specified. Normally, a routine servicing of an aid is within the capacity of the tender assigned; however, there must be a check made of the inventory of aids to navigation equipment aboard the tender. This check may reveal that the tender has utilized so much equipment correcting outages that she must return to the depot for resupply before attempting the routine servicing.

The Geographic System. The most crucial list of parameters which must be programmed in the Operations Calculator is the list which specifies the geographic system of the model and the decision rules which prescribe the normal cruising of the tenders and cutters.

A simple geographic system to simulate is the one described by a river. On a river all aids must be along the channel, and the tender must proceed past them in a prescribed order. It is not possible to skip any aids except those in side channels, and then

the whole side channel can be skipped. Not all layouts of aids to navigation systems fit this confining pattern. It is quite possible that many alternative routes are available, each of which will enable the tender to pass the aids in a different order. The programming of the model must allow for these alternatives; the decision rules must be available to specify which alternate routes will be followed.

Consider the situation in the Chesapeake Bay area. A coastal type tender leaving the depot, which is located in Berkeley, Virginia, must pass aids in a certain order to reach the open bay. However, once there, several alternative routes are available, either following prescribed channels or even proceeding outside channels to short-cut the route to a particular aid.

The route to be followed must be specified and acceptable alternates identified. Actually, this is not difficult to do on a computer. A normal route may be specified. In the river system, this would be the possible route; in another system, a decision rule or policy would establish normal. For a non-confining geographic system, points at which alternate routes are possible can be identified. The model can be directed to examine the alternatives available and choose the one which fits best our built-in policies. The rules can be phrased to consider the time to reach destination by each alternate, the maximum number of aids which can be worked in a given

time by each alternate, the barring of alternate routes which must be included in the geographic system but by policy or decision are closed to the tender.

This section of the model may also be refined to include the effects of weather, tides, or time of day on the passage of the tender. However, such refinements must be important to the evaluation of the simulation or omitted from the model, for they are complications.

The geographic system of the model is also the basis of the calculations to describe the operations of the cutters and tenders when performing SAR duties. Any restrictions, lifting of restrictions, or varying decision rules applicable to such situations must be programmed. For instance, it may be "policy" for the vessels to proceed at slow speed in some channels but to allow maximum speed when on a distress case. This would change the times for a vessel to traverse the channel from the routine situation to the distress case.

Search and Rescue and Tender Orders. Search and Rescue cases and Tender Orders present no special difficulties to the Operations Calculator. Parameters and Decision rules must be programmed to define and describe the possible situations and specify selected solutions. Like the situation for aids to navigation work, the time to accomplish each type task can be specified or the times to

accomplish sub-tasks can be listed and the model allowed to select and sum the applicable times to determine the total time for a particular order.

Depots. The work of the depots is simulated in the Operations Calculator. This consists of computing the time necessary to accomplish the work specified by the Decision Section and fitting this work into the allowed man-hours per day of the depot. In addition, accomplishment of the work is used to update inventories. For this purpose the depot may be considered to have three "inventories": (1) work to be done--the aids to navigation equipments awaiting overhaul, (2) buoys, equipments, and appendages in stock, and (3) prepared buoys, equipments, and appendages ready for loading by the tender. The Operations Calculator computes the movement of items among these three inventories.

It may be easier to visualize the aids to navigation equipment being always located in one of two places: "on station" as maintained by the Status Generator, or "at the depot" as maintained by the Operations Calculator. The tender, conceptually, is the transitory state which shifts the equipment from one place to another.

Light Attendant Stations. It has been stated that Light Attendant Stations are included in the model. The activities of these stations, if included in the simulation, are computed by the

Operations Calculator. In concept, these stations are buoy tenders of limited capacity. As long as parameters and decision rules are included which describe such stations' capacities, the model can handle their simulation as well as that of the tender.

## Summary of the Operations Model

In summary, the Operations Calculator is programmed with parameters and decision rules which describe the capabilities of the tenders, cutters, depots, and light attendant stations whose operations as part of an aids to navigation maintenance system and search and rescue agency are being simulated. As perhaps the most important set of parameters, the Operations Calculator includes a programmed description of the geographic area being studied. In operation, the Operations Calculator assists the Decision Section by computing the results of proposed assignments and reports these results to the Decision Section for selection. The Operations Calculator keeps track of the performance and assignments of every cutter, tender, depot, and light attendant station in the simulation. For this purpose, it calculates the times to accomplish each assigned task, keeps tabs on vessel position and units' present occupation, and maintains the inventories and states of the aids to navigation equipments aboard each unit. As a final function, the Operations Calculator prints out operations reports of all simulated units for any period desired and feeds inputs to the Accounting Model for its use.

## The Accounting Model

The Operations Model already described will simulate the workings of a system of cutters, tenders, depots, and light attendant stations in their assigned tasks of search and rescue; maintenance of aids to navigation; and, for the vessels, performance of other operation duties. This model can present the results of changes in decision rules (policies) established by the Coast Guard and engineering innovations which might give rise to changes in policies. These simulations will be presented in the form of operations reports. However, the decision to go ahead with any project or policy change is frequently also based on costs and/or money. It is for this reason that the Accounting Model is proposed.

The Accounting Model, which is much simpler in concept than the Operations model, would simply price out the operations simulated by the Operations Model. It would utilize a list of costs, programmed as parameters, which it would use to price out the operations and prepare cost reports for all units. This list of costs could be actual costs as determined from real operations, or it could consist of postulated costs proposed to test the results of changed policies or engineering specifications. The major advantage of this model is its provision of cost reports which can be used to measure the results of changes to the system. Operations are the basis for measuring the effectiveness of vessels in the Coast Guard, but money

is the measure which will, to a great extent, determine whether the Coast Guard will be able to meet its commitments. Certainly, its use in evaluation and justification warrants its inclusion in the simulation model.

## CHAPTER VII

## CONCLUSION

To assist the mariner guide his vessel along our shores, our rivers, and our lakes, and into and out of our ports, the United States maintains extensive navigational aids. This system of aids is justified by the number and the value of the vessels and their cargoes which ply our waters. The increase in insurance rates alone which would result if the system did not exist would prompt urgent cries to create such a system. The delays to vessels slowly feeling their way into our ports would cost fortunes.

The United States Coast Guard is charged with the responsibility for establishing, maintaining, and operating the American system of aids to navigation. This is just one of the essential services in the Coast Guard's broad responsibilities for safety of life and property at sea.

Any organization with multiple goals finds itself, at times, operating under compromise solutions to its problems. This comes about from several factors, but may be summed in the phrase of economics, "the allocation of scarce resources among competing ends."[1] Pressures grow within an organization to modify policies, to shift procedures, to adopt new equipments, to stress more this

1. This phrase has been emphasized in his classes by Dr. W. W. Soujanen, U. S. Naval Postgraduate School.

function or that function to the detriment of others. Yet the organization remains committed to performing all its functions. What the organization leaders need is a priority system of intermediate goals which give proper emphasis to each function of the organization together with a method to determine the results of a proposed change before that change is adopted.

Before undertaking the effort to establish a priority system of intermediate goals or devising a method of testing proposals, the organization leaders must feel that the rewards to be gained justify the resources to be expended.

The Coast Guard is charged by law with several functions: (1) enforcement of laws on the high seas and American waters, (2) inspecting the vessels and licensing or issuing certificates to the personnel of the merchant marine, (3) providing a search and rescue service on the high seas and on American waters, (4) establishing, maintaining, and operating a system of aids to navigation, (5) conducting ice breaking operations as required, (6) maintaining a state of readiness to operate as a part of the Navy in time of national emergency. Although these functions (except No. 6) support the common goal of increasing safety of life and property at sea, they all compete in various ways for the limited resources available to the Coast Guard. Valiant efforts have been made to increase the resources available to the service

with some success. However, the present world situation, the limitations placed on the national budget, the tax rate now imposed on the economy, and the priority of Coast Guard functions within the general needs of the country indicate continued restrictions on resources. The Coast Guard must seek increasingly efficient methods of performing its functions if it is to remain capable of accomplishing them.

The methods of Operations Research pioneered during World War II offer a way of studying the whole Coast Guard as an operating system. Such studies promise means of measuring the actual relationships between the various functions. These measures, if determined, would form the basis for the division of resources among the functions. It is essential that these functions be studied as the united whole that is the Coast Guard, because each function (except No. 6) was at one time the single goal of organizations which no longer exist. These former organizations gave chief emphasis to each function. The Coast Guard has been formed and given the primary purpose of striking an effective balance of these functions.

The high speed digital computer has become an essential adjunct to the methods of Operations Research. These machines have provided rapid answers, at relatively low cost, to the myriad calculations necessary to obtain solutions to Operations Research models.

Such machines have made possible the adaptation of Operations Research to problems heretofore considered impractical to tackle. The results have been rewarding.

As this paper has tried to prove, the construction of a conceptual model to simulate the operations of a Coast Guard District is feasible. Such a model, if programmed on a computer, will enable the service to measure its present performance, to highlight problems, and to reveal policies and procedures which need to be improved. When programmed with proposed changes of policy, procedures, or equipment capabilities, the computer model will simulate the effects of the changes on the District's operations and, thereby, produce realistic data to form the basis of decision.

The Monte Carlo technique of using a probability conditioned random sampling to construct a simulated version of the District's operations has been chosen, because this technique is readily adaptable to such a problem. Even more important, however, is the ability to manipulate the model so constructed to consider the effects of real or proposed changes. This adaptation to change without having to construct a new model, alone, recommends the Monte Carlo method for consideration.

This paper presents a model of an aids to navigation maintenance system having variable responsibilities for the performance of search and rescue duties and tender orders. Such a model requires

the determination of the values of a considerable number of parameters. When these parameters are available, the necessary steps to program this model (or a revised one) follow in order. With the model programmed, the computer will produce the data needed by the Coast Guard: (1) to provide a priority system of intermediate goals which will give due emphasis to each service function, and (2) to evaluate proposed changes of policy, procedure, or equipments <u>before</u> such changes are made without endangering personnel, equipments, or present operations.

BIBLIOGRAPHY


IBM Mathematics and Applications Department. Job Shop Simulation Application, Preliminary Write-up, 1959; Revised, 1960. New York, N.Y.: International Business Machines Corporation.

Maritime Transportation Research Symposium, 3rd Conference, 1959. Research Techniques in Maritime Transportation. Washington, D.C.: National Academy of Sciences - National Research Council, Publication 720, 1959.

Miller, David W., and Martin K. Starr. Executive Decisions and Operations Research. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1960.

United States Coast Guard. Aids to Navigation Manual, through Amendment No. 4 of 1956, CG-222. Washington, D.C.: Government Printing Office, 1953.

United States Coast Guard. Complete List of Lights and Other Marine Aids, Atlactic Coast of the United States, Volumes I - V, CG-158. Washington, D.C.: Government Printing Office, 1960.

Weldon, Foster L. Operational Simulation of a Freighter Fleet, a paper presented at the Maritime Transportation Research Symposium, 1959. (See above.)

Willoughby, Malcolm F., Lt., USCGR(T). The U.S. Coast Guard in World War II. Annapolis, Md.: United States Naval Institute, 1957.